

Morpheme House System

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Renewing Prefabrication

Prefabrication is often associated with the technological advances of the Modern Movement, and many 20th century projects endeavored to produce compelling solutions for housing using the most advanced materials and methods. Housing and prefabrication have long been coupled in experiments that range from the simple and practical to outlandish and unbuildable theoretical proposals. In many cases these projects have sought to examine ways that new technologies and delivery methods could contribute solutions to larger social issues, such as lack of available affordable—and well-designed—housing. Most proposals, however, did not gain mass-appeal or serial implementation, and some failed in dramatic fashion due to economic, technological, and aesthetic issues.

The current resurging interest in prefabrication is the result of—among other things—new digital design and fabrication processes as well as a belief that prefabrication can produce sustainable solutions for housing. In the past decade, designers have suggested that prefabrication techniques and mass production/customization can generate housing that makes more efficient use of fossil fuels, materials, and construction time.

Another key factor fueling the renewed interest in prefabrication is current anxiety associated with the architect's expanding roles. The concepts of Integrated Practice (IP) and emergent design tools such as Building Information Modeling (BIM) have called into question the traditional responsibilities of the architect. If IP suggests that building systems and design processes have become so complex that the

architect must serve primarily as an information manager, then perhaps BIM gives the architect greater control over systems and performance. Some have stated that the architect should increase his or her roles to include project development¹ and design-build, thus restoring the architect as "master builder."² Research has gained a more significant role in practice, and many architects are producing measurable components and prototypes within offices that resemble workshops. Laser cutters and rapid-prototyping 3D printers complement table saws and have increased the degree to which architects can integrate digital and physical modeling into their design research and experimentation. Digital tools have enabled prototype design, construction, and testing to become a viable and significant means of exploration and innovation in contemporary architectural practice.

As a "first full-scale and usually functional form of a new type or design of a construction,"³ prototypes have become a significant component in critical design practices. Though the term prototype suggests the typical, or what is already well known, architectural practices are using iterative prototype production in order to innovate. These practices identify cultural, technological, and contextual influences on the methods of making while considering the virtues, deficiencies, and consequences of mass production, prefabrication, rapid construction, design/build, flexibility, and modularity.

Mapping Fuller

Buckminster Fuller was an early pioneer of prototype and prefabricated housing. He transformed cylindrical corrugated metal grain bins into emergency shelters, and his Wichita House made use of materials and production methods of the aircraft industry. In the 1940s, Buckminster Fuller produced a series of world maps that were based on unfolded polyhedral geometry. The maps were significant in their conceptual and representational techniques, and formed a more accurate, less distorted two-dimensional rendering of the three-dimensional globe. The maps—which depicted continuous continental landmasses and efficient straight-line shipping lanes—became a cartographic component in Fuller's famous collection of neologistic Dymaxion (Dynamic+Maximum+Ion) projects that also included automobiles and prototype houses. The map is a "topological transfer of high frequency form of Fuller's totally-triangulated

systems from the surface of a sphere to the equivalent triangular spaces on the faces of a polyhedron."⁴

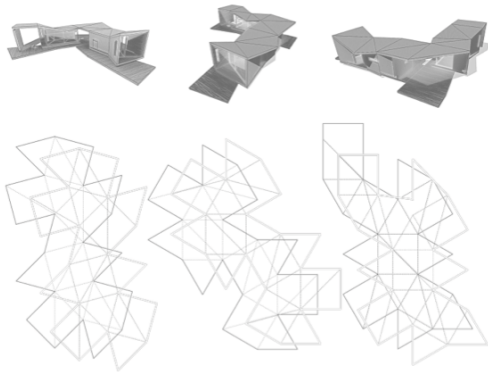


Fig. 1. Translating Fuller's maps

The Dymaxion maps show a transformation from sphere (3-D single surface) to planes (multiple 2-D surfaces), and they provide an unfolded, two-dimensional representation of a volumetric spheroid. My theoretical proposal for the Morpheme House System reverses this process to recombine the basic triangulated components (typically isosceles or equilateral) of the mapping system to produce variable and customizable three-dimensional architectural form (Fig. 1).

The conceptual framework for the Morpheme House System project is derived from Fuller's Air/Ocean/World Maps and linguistic coupling of morphemes. A morpheme is the "smallest meaningful unit in the grammar of a language,"⁵ and this project proposes a panelized system that can be linked additively to define internal and external spatial configurations.

Material Systems

Just as morphemes in language rely on combination (and re-combination) to produce words and meaning, the Morpheme House System relies on unitized triangular panels constructed of structurally insulated wood and foam sandwich panels (SIP), to create form, space, and meaning.

Structural insulated panels are the primary construction system in Morpheme Houses because they are versatile components that can be used as floors, walls, and roofs. The wood and expanded polystyrene sandwich panels—which are manufactured in various

thicknesses—can be configured for structural stability and high insulating values. The SIPs panels have a high strength-to-weight ratio that makes them sufficiently strong for residential spans that can be achieved with relatively shallow cross-sectional depth. Splines that run along panel joints offer structural rigidity, but create a thermal bridge that compromises the continuity, and therefore integrity, of the insulation. For this reason, panel layouts for projects must be considerate of structural and thermal requirements, and arranged to optimize both.

Houses constructed with insulated sandwich panels typically offer greater thermal resistance values than more conventional wood frame structures because there are fewer studs that create thermal bridges. SIPs that are properly designed and installed lower the need for mechanical heating and cooling, but tightly-sealed building envelopes present some concerns for ventilation. Joints and other cracks and voids in SIPs must be sealed with expanding foam. This restricts air movement and produces a building that does not "breathe" naturally. Houses constructed of SIPs typically require a mechanical means of air exchange to control humidity and prevent the deleterious effects of moisture build-up on the wood surfaces. The mechanical ventilation systems can be augmented by designs that encourage natural cross-breezes to move through the interior.

Because SIPs are a relatively new technology, some building codes do not specifically address their implementation. In many jurisdictions, buildings constructed primarily of SIPs must meet guidelines established for Type V wood construction. This limits the scale and possible uses of SIPs, but the panels are acceptable for most residential applications. Fire resistance issues for SIPs are similar to traditional 2x wood framing, and a 15 minute thermal barrier (1/2" gypsum wall board, for instance) is required on the interior panel surface for a more robust fire resistive assembly.

SIPs can be adapted to fit modular and custom layouts; and though they are factory-produced, they can be easily altered on-site using basic tools. Circular saws or modified chain saws are used to trim the oriented strand board panel skins, and a tool equipped with a heated wire removes sections of the EPS foam core. Careful planning and precise drawings ensure that panels will be manufactured to

proper overall dimensions, and that openings for doors and windows are accurately located. With most projects, however, erectors on-site are required to make at least minor panel modifications. Though site modifications slow the installation process, a well-planned and executed kit of SIPs can be constructed in a fraction of the time required for typical stick-built, balloon-framed structures. Projects composed of large panels may require a crane and ratchet straps to set walls and roofs in place.

The panels are ideal for prefabricated housing systems, kits that rely on in-situ construction, and hybrid approaches that combine the efficiencies of the factory with on-site improvisation. In fabrication shops, the panels can be manipulated with computer-numerically-controlled machines that are programmed to cut, carve, and drill the OSB skin and the foam core. CNC machinery allows a closer relationship between the tools of design and the tools of production, placing more control—and perhaps liability—in the hands of the architect.

Theoretically, shop production has several advantages over work done on-site. These benefits include greater precision, less material waste, increased worker safety, and no weather delays. Although factory production has the potential to improve quality, designers must consider methods, and therefore constraints, of shipping shop-fabricated modules or panels to sites. Costs and risks (including damage to structure) associated with delivery processes present a challenge to designers and construction managers alike, and can easily undermine the advantages of prefabrication.

A distinct advantage in utilizing SIPs is their ability to accept an array of cladding materials. The oriented strand board provides a substantial continuous nailing surface on the interior and exterior faces. Other panelized or modular materials such as sheet metal, masonry, wood siding, shingles, and cement board can be used in conjunction with building wrap and cavity weeping materials to create waterproof assemblies. Some cladding materials such as asphalt shingles may require the installation of furring strips on the face of the panels to provide a cavity for ventilation. SIPs are also compatible with numerous window and door systems.

SIPs are composite materials that offer design flexibility, but they also pose several challenges to the construction process, particularly for the plumbing, mechanical and electrical systems. Drawings require careful coordination to ensure that chases are accurately located and sized within the panel's foam core. Routing chases on-site is possible, but often difficult. Larger chases are typically limited to the building's interior where standard 2x framing is used and continuous insulation is not undermined.

Joinery also poses a challenge to detailing foam/OSB composite panels. The most common joint is created by inserting 2x lumber splines (equal in width to the foam depth) along the panels' perimeter. These splines are held in place by glue and face nails through the OSB skins, and they provide a simple rigid, nail-able material for attaching panels to each other along edges. Joints are carefully engineered to provide sufficient structural capabilities. A key part of the research for this project included producing alternative joint assemblies to accommodate faceted panel configurations. In some instances, conventional wood joints offer the most economical and elegant solutions. In other arrangements, steel inserts are used to connect panels and provide a top plate for fitch columns that transfer vertical loads (Fig. 2).⁶

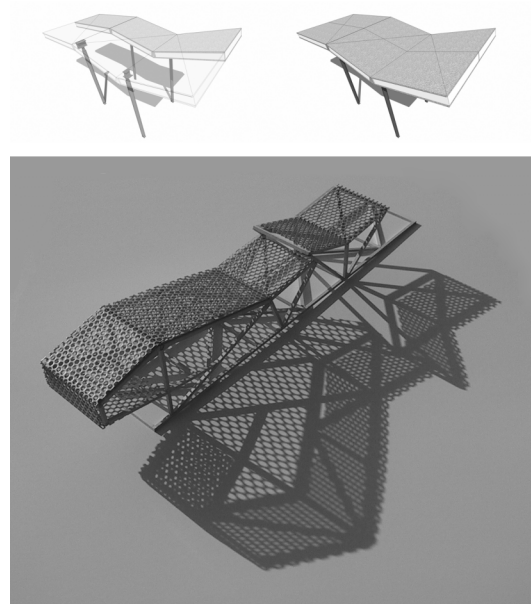


Fig. 2. Column/spline detail; Study model: spline wireframe.

Triangulating Panels

The Morpheme House panels are triangulated based on the geometry of the Dymaxion maps, and their spatial/formal arrangement provides an alternative to orthogonal systems that typify most prefabricated panel and box systems. In linguistic models, the meaning of a morpheme may vary depending on its immediate environment, and this suggests that contextual specificity (building site) should be a determinant of planar and sectional form in the Morpheme House System. Consequently, the system can be configured to respond to site characteristics including topography, hydrology, view, solar orientation, and other natural elements. The system relies on triangulation and facets that are derived from geometrized topological form. As the root of the project title suggests, the system of panels can be utilized to create various morphological arrangements that are derived from formal growth patterns and site-specific topographical meshes.

The Morpheme House System is a theoretical project that seeks to engage prefabrication methods with digital design, modeling, and scanning technology. More importantly, the project examines possible solutions to a chief criticism of prefabricated housing: in its attempt to provide universal design solutions, prefabricated housing neglects to address specific site conditions. The Morpheme House draws inspiration from Buckminster Fuller's technique of reorganizing maps, and the triangulated polyhedral geometry that constitute his Dymaxion Air Ocean World Maps. The System seeks to produce meaningful relationships between prefabrication and site by establishing digital technology as a mediator.

Translations from Topography to Building

In the preface to *Uncommon Ground: Architecture, Technology, Topography*, David Leatherbarrow develops a thesis that "place and production, or topography and technology, are in conflict in late modern architecture, because while technical objects incorporated into buildings are conceived independent of territorial considerations, constructed buildings never are."⁷ Leatherbarrow also questions whether "global technology destroy[s] topographical coherence and cultural continuity."⁸ Though critical of the object-like tendencies of modern architecture, he points to the work of Antonin Raymond, Aris Konstantinidis, and Richard

Neutra, citing each for creating buildings that "were carefully tuned to their locations, but not in traditional ways."⁹

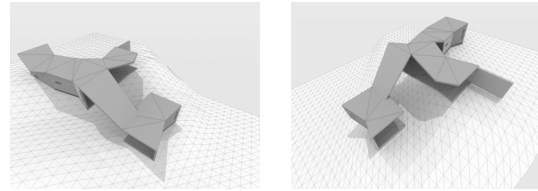


Fig. 3. Approach 1

The Morpheme House System proposes design processes that link building to site in non-traditional ways. In the first approach, topological data is translated into building form. In the second approach, morphological transformations alter the formal language of conventional house types, adjusting them to specific site conditions.

Approach 1

The first approach begins by digitizing site topography using information from existing maps or by obtaining data with airborne optical remote sensing technology such as L.I.D.A.R. (Light Detection and Ranging). Using surface modeling software, the contours can be regenerated as triangulated mesh networks that produce a faceted polyhedral interpretation of the site. The polyhedral site surface is composed of triangulated faces that attach continuously along edges. The triangulated components can be extracted from the terrain model and recomposed as faceted structure/surface building components including floors, walls, and roofs (Fig. 3).

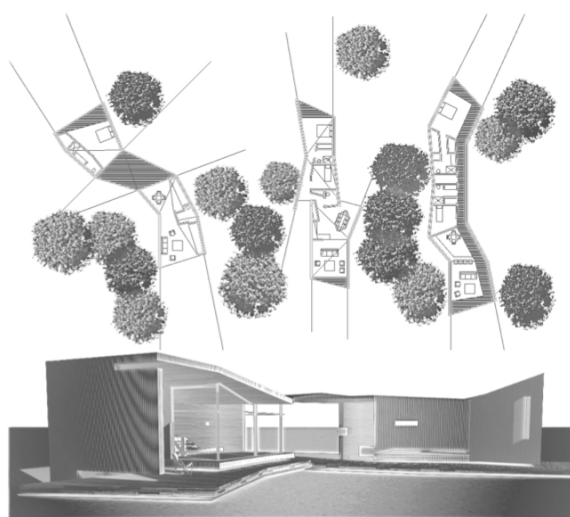


Fig. 4. Modified house plan types: dog-trot, shotgun a, shotgun b (l-r); View of Dog-trot "L".

Approach 2

In the second approach, the house designs are based on traditional house types that engage their sites through transitional zones such as porches, balconies, and courtyards. Dog-trot and shotgun houses, courtyard schemes, and multi-unit aggregations provide model forms that can be transformed in response to site conditions (Fig. 4). These house types provide basic functional precedents and programmatic patterns for prototypes in the Morpheme System.

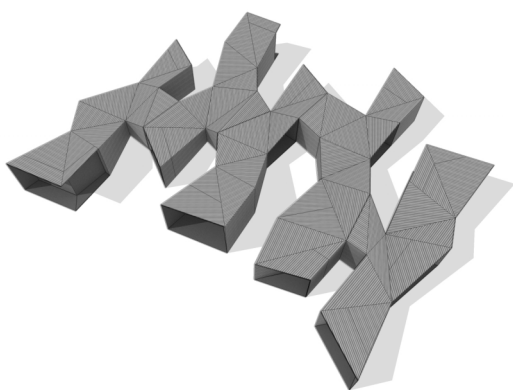


Fig. 5. Aggregation: multi-family courtyard housing

In each approach, The Morpheme House implements an "open system" of components that allow for factory and on-site customization of form and finish material. The system at-

tempts to engage Fuller's ideas of "ephemeralization,"¹⁰ a term that suggests components and processes that produce maximum results with minimal means. To this end, the Morpheme House employs stressed-skin panel floors, walls, and roofs that conflate structure and surface while allowing for variations in spatial configurations and material finishes. The systems seek efficient material use and rapid construction processes. The stressed-skin panels are connected along edges and can be set at various angles to produce structurally rigid floors and roofs.

Leatherbarrow observed (in the work of Neutra, Raymond and Konstantinidis) that "walls, the traditional element of architectural definition and platform compartment, came to have less a role in defining settings than the platforms themselves, the floors, ceilings, and intermediate levels."¹¹ In the Morpheme House System, the roofs and floors are the primary planar elements that modulate to form a dialogue between house and site.

The Morpheme House system explores the flexibility of a SIPs-based system to bring greater formal diversity to typical orthogonal prefabricated prototypes. The panels can be composed into small modules in shops or packed flat for delivery to the house's site. Panels and modules can be aggregated to produce small-scale single-family homes or extended to form dense multi-family dwellings (Fig. 5).

The Morpheme House provides a flexible system that makes prefabrication a viable approach to site-specific design. The panelized components and modules impart systematic variability and can be modulated to diverse site conditions.

Within the Dyamaxion cartographic series, Fuller created reconfigurable modular maps that shifted perceptions of geography on a global scale. The Morpheme House endeavors to accomplish a comparatively modest—but essential—goal of intensifying the perception and experience of site on a local scale.

Notes

¹ Jonathan Segal, FAIA has been a proponent of architects developing projects.

² Kieran, Stephen and James Timberlake. *Refabricating Architecture*. New York: McGraw-Hill, 2004. p.27.

³ Miriam Webster On-line Dictionary.
<http://www.merriam-webster.com/dictionary/prototype>

⁴ Fuller, R. Buckminster and Robert Marks, *The Dymaxion World of Buckminster Fuller*. Anchor Books Edition, 1973. p. 50.

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<http://www.sil.org/LINGUISTICS/GlossaryOfLinguisticTerms/GlossaryLinguisticsM.htm>

⁶ For information on structural insulated panels, refer to:

Morley, Michael. *Building with Structural Insulated Panels (SIPs): Strength and Energy Efficiency Through Structural Panel Construction*. Taunton Press, 2000.

and Structural Insulated Panel Association (SIPA):
<http://www.sips.org>

⁷ Leatherbarrow, David, *Uncommon Ground: Architecture, Technology, and Topography*. Cambridge, MA: MIT Press, 2002. p. vi.

⁸ Ibid., p. vi.

⁹ Ibid., p. viii.

¹⁰ Baldwin, J., *Bucky Works: Buckminster Fuller's Ideas for Today*. John Wiley and Sons, New York: John Wiley and Sons, 1997. Pp. 14-23. The book provides a more complete description of the term.

¹¹ Leatherbarrow, p. viii.